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[*Extracted from the* Geological Magazine, February, 1877.]
Trübner & Co., 57 and 59, Ludgate Hill, London.

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THE LHERZOLITE OF ARIÉGE.

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THE rock Lherzolite has been described by Prof. Zirkel in his valuable Beiträge zur Geologischen Kentniss der Pyrenäen (*Zeitschrift der Deutsch. Geol. Gesel.*, vol. xix. p. 68), but is generally passed over with the briefest mention or entirely omitted in English works on Geology. Even in Cotta's "Rocks Classified and Described" it is barely noticed, and the word is left out in the index. On this account, and seeing that, so far as I am aware, no description of its microscopic structure has yet been published, a notice, embodying the results of Prof. Zirkel's paper, and of a brief visit of my own to this not very accessible locality, may be useful to students.

Lherzolite is a crystalline aggregate of the minerals olivine, enstatite, and diopside, with some picotite, in texture varying from finely to rather coarsely granular; that from the locality visited by myself being, on the whole, of the former character. It obtains its name from the Etang de Lherz, a small tarn in the Eastern Pyrenees (Dept. Ariége), above Aulus, in the valley of the Garbet, 38 kil. from St. Girons, and near the Col d' Ercé (or Port de Lherz), an easy pass (5341′) leading to Vicdessos in the valley of the Oriége. The rock entirely surrounds the *Etang*, and is the largest of a linear series of seven exposures in the vicinity of Vicdessos.

The Etang de Lherz is a shallow tarn occupying apparently a true rock-basin, the longer axis of which lies roughly N. and S. The water escapes from the northern end by soaking through some peaty ground. On the western side is a tiny island. The tarn is surrounded by rounded masses (probably once ice-worn) and fallen blocks of the Lherzolite, which also rises from the western shore in a craggy hill. A furlong or less from the eastern shore limestone shows through the grass and stretches away in that direction, forming the general mass of the country. The tarn is not in the line of the main valley of the Garbet, but in a sort of open upland glen, a little

above the bed of the former. On the opposite side of this rises a bare craggy limestone hill, capping the Lherzolite which forms its base.

The Lherzolite is tough and difficult to break, traversed by many minute, rather irregular, divisional planes, with occasionally a slight tendency to a platy structure. Hence it is not easy to obtain good specimens. The surface of a specimen from the heart of the rock is rough, rather uneven and granular, at the first glance tolerably uniform in colour and apparent composition, of a dark greenish-grey or olive-green colour. A closer examination shows specks of brighter green, generally of two colours, one (the more invariable) an emerald green, the other a waxy-looking duller green; also specks of a resinous pale-brown mineral, sometimes with a platy or fibrous aspect and a dullish lustre ranging from silvery to brassy. Minute grains of an irregularly disseminated black mineral, with a vitreous lustre, are also just visible; and there is another of transparent glassy aspect. The last is only broken olivine, to which the predominant dull-coloured mineral belongs; the emerald green is the diopside; the resinous mineral enstatite; and the black is picotite. The duller green tint is serpentine. The separate minerals are more easily detected in a coarser specimen, which I purchased from Pisani in Paris in 1875, who obtained it from Sem, the easternmost locality along this line of outbursts in the Department of Ariége.

The rock at the Etang de Lherz varies a little in texture, some, especially, as it appeared to me, that towards the outside, being more compact than the rest. When the rock is slightly decomposed the dull green tint becomes more marked, and the compact varieties begin to resemble serpentine. The exterior weathers from a bright yellowish to a dark rusty-brown tint, with a rough surface. On this the projecting pale amber-yellow grains of enstatite, and the bright green grains of diopside, with the black picotite, may be readily distinguished. Occasionally also a sort of linear structure is developed on the surface in weathering; such as I have observed in some of the Lizard serpentine; like this, it has some connexion with an internal parallelism, but the exact nature of it is not yet quite clear to me, though I think it will prove to be connected with a fluidal structure. The brown weathered surface generally extends inwards for about ·1 to ·2 inch; and the change from it to the green rock is pretty sudden, a thin pale band usually intervening, in which the enstatite, diopside and picotite are well distinguished. The rock is traversed by numerous irregular joints, breaking it up into rude polygonal blocks; but now and then the outside of an old weathered surface shows a more regular prismatic structure; occasionally also there is a slight parallelism in its fissures. The more minute joints are lined with a thin film of limonite or of a serpentinous mineral, apparently a green steatite,—often in the latter case so thin as to be a mere glaze. Slickensides are not rare on the joint faces. The general aspect of the weathered rock, the peculiar roughened surface with its irregular fissures, the jointings and contours of the fallen blocks, in shape like masses of broken curd, strongly reminded me of the Lizard serpentine in Cornwall, with which I am very familiar.

Time did not allow me to cross the valley and examine the junction with the limestone on the opposite side, where it was well exposed for a considerable distance at the base of a sort of cliff; but as far as I could see it was rather wavy and uneven, as if the Lherzolite were intrusive. I followed the junction on the east side of the pool for a considerable distance. Unfortunately the abundant herbage, the number of scattered boulders, and the peculiar weathering of the limestone, which forms deep fissures (like the *karrenfelder* of the Alps), harbouring a rich vegetation, prevented me from obtaining a single actual contact: but as the Lherzolite clearly appears here and there to protrude in broad tongues into the limestone, and this is highly crystalline (being quite white and saccharoidal) near the junction, I have little doubt the rock is intrusive. That it is an igneous rock I think no one who has examined it will dispute. There are, however, I think, no proofs of eruption, though a breccia of angular fragments of Lherzolite and limestone might seem at first sight to be a volcanic agglomerate, and so even favour the idea of contemporaneous volcanic action. According to Prof. Zirkel this breccia occurs here (and here only) between the Lherzolite and the limestone. I did not, however, observe it at this part of the junction, but found a dyke-like mass of brecciated Lherzolite on the opposite side of the Etang. The numerous fallen blocks made it difficult to examine this *in sitû*, but it appeared to be about three or four yards wide, and to cut across the Lherzolite roughly from E. to W. As far as I observed, however, this rock was composed only of Lherzolite, and I fully believe it only to be a friction breccia, and not at all of the nature of a volcanic agglomerate. The other masses of breccia which I examined were on the grassy hill-side nearer to the Col d' Ercé, not far from where there is another small patch of Lherzolite on Prof. Zirkel's sketch-map. These, however, appeared to me to be in every case erratics, and I could not see the rock *in sitû* on the hill above. My time, however, was too limited to allow of a long search. These blocks varied from a breccia of angular and subangular fragments of Lherzolite, frequently more than three inches in diameter, imbedded in a ferruginous paste which often appears to consist mainly of minute fragments of Lherzolite, to an extremely pretty rock chiefly composed of fragments of white marble, often from a half to one inch diameter, imbedded in a speckly yellowish or greenish grey matrix, with a slight ruddy tinge. In the time at my disposal I collected four varieties of the breccia, forming a fairly complete series. The first is exclusively made up of Lherzolite, and so thoroughly compacted that (as in many ancient breccias) it is often not easy to distinguish the fragments, except on a weathered surface. The second consists mainly of Lherzolite fragments with a very few small pieces of marble, but here and there there is an appreciable proportion of minute calcareous fragments in the matrix. In the third, the marble predominates, but the paste contains a large quantity of comminuted Lherzolite; and in the fourth fragments of marble abound, but those of Lherzolite are rare, though this rock

is represented to some extent, as in the last, in the paste. In this (in the last two cases) one can readily distinguish bright green fragments of diopside and rather numerous black grains of picotite, apparently imbedded separately.

This mass of Lherzolite is the largest of the seven exposures in the district, and according to Prof. Zirkel is about 1300 yards in greatest length. Three other masses lie near it along the line of the little glen of the Suc. The rest are near its junction with the Oriége, one being on the opposite bank near the village of Sem. All are in the Liassic rocks, and, except the last, are very near their junction with the granite, which even here is at no great distance. It is also more coarsely granular than the rock at the Etang, and the breccia is wanting. Lherzolite also occurs near Portet d'Aspet, in the upper Val longue (Castillon), and on the south side of the Col de Lurdé, in the neighbourhood of Eaux Bonnes. The principal rock here is a limestone with ophite, *i.e.* greenstone, near it. I have not seen any of these.

The rather compact condition of the rock, and the fact that the olivine is in some specimens rather green, and the diopside a little dull in colour, while the enstatite does not always exhibit its characteristic tructure, makes it often very hard to distinguish the component minerals of the specimens from the Etang de Lherz. They are better seen, however, on a polished surface, and can be separated, as Zirkel suggests, by treating the pounded rock, first with hydrochloric acid, and then boiling it with caustic potass. In my Pisani specimen from Sem, the minerals are much more easily distinguished, as is the case also, according to Zirkel, in his specimens from this locality. The composition of the Pyrenean Lherzolite is according to an old analysis (Zirkel, p. 140):—$SiO_2=45{\cdot}0$, $Al_2O_3=1{\cdot}0$, $CaO=19{\cdot}5$, $MgO=16{\cdot}0$, $FeO=12{\cdot}0$, $CrO=0{\cdot}5$, with a trace of MnO and loss$=6{\cdot}0$. Lasaulx gives the analysis of a Lherzolite from Norway (Elem. der Petrograph. p. 338):—$SiO_2=37{\cdot}42$, $Al_2O_3=0{\cdot}10$, $MgO=48{\cdot}22$, $FeO=8{\cdot}88$, $MnO=0{\cdot}17$, $NiO=0{\cdot}23$, $H_2O=\cdot 71$.

The rock varies slightly in different parts around the Etang, both in grain and in preservation. I collected specimens chiefly from near the southern end, and about half-way down the west side; the most serpentinous specimens coming from the former. Mr. S. Allport, to whom I gave a duplicate from Sem, kindly cut me a beautiful slide from it, and I have had slides (six in all) cut from three varieties collected by myself at the Etang. I will refer to them as No. I. (from Sem [Pisani]), No. II. (specimen from the west side), No. III. (specimen from the south end), No. IV. (specimen showing a partial passage into serpentine). This specimen was cut close to a joint face where the change was greatest.

Microscopic Structure.—In all cases the rock is normally composed of olivine, enstatite, diopside, and picotite, with occasional minute specks and microlithic aggregates of an opaque black mineral, probably magnetite. Microliths of other minerals are rare. The first three minerals all occur in variable shaped grains; those of the olivine roundish; the diopside occasionally showing a slight

approach to a regular crystal outline; the enstatite usually irregular and longish; the olivine appears to have crystallized the first, but I think the difference has not been great. It generally forms about $\frac{2}{3}$ of the whole mass of the rock. The picotite, from its shape, seems to have crystallized last.

The olivine occurs in more or less rounded, transparent, colourless grains, very irregular in size. Surface finely granular, something like frosted glass. Colours with crossed Nicols often very beautiful, commonest from a translucent greenish yellow to a yellowish green, and from a bright to a purplish pink. Owing to the peculiar texture, one of these tints often overspreads the other something like a shot silk. The mineral shows the usual rather irregular cracks, indicating its imperfect cleavage. These often cause, by imperfect cohesion, colour bands, which are also common near the edges of the grains. Not seldom we find in the olivine small vermicular cavities arranged in slightly wavy bands. These appear to be sometimes empty, sometimes filled with a brownish mineral, perhaps iron peroxide. They lie in some cases in the planes of imperfect cohesion, and then have often a dendritic character. There are occasional clots of an opaque dust-like mineral, probably magnetite, and thin fibrous brown films, strongly dichroic, which may either be mere stains or minute plates of iron-glance. The last are often associated with the picotite.

The enstatite is transparent, colourless in ordinary light, with a finely granular or slightly silky texture. The cleavage parallel to $\infty\breve{P}\infty$ is generally well exhibited, though not so close as a rule as in diallage; a more interrupted cleavage parallel to ∞P is also sometimes fairly distinct, as in Rosenbusch, Mikroscop. Physiogr. Tab. viii. 44. In cases where the specimens have a less characteristic aspect, I have found the principal cleavage planes better exhibited by rotating the microscope stage till the plane of the principal cleavage is nearly parallel to the plane of vibration of one of the crossed Nicols, when, as the crystal approaches its darkest aspect, the fine cleavage becomes more clearly visible. This method (proposed by Tschermak) of distinguishing the orthorhombic enstatite from the monoclinic diallage will be found very useful in examining Lherzolite. The crystals show sometimes wavy bands crossing roughly at right angles the lines of the principal cleavage, formed apparently by minute elongated cavities and microliths. Colours with polarized light pale yellowish or greyish to various blues.

The diopside is not generally in well-formed crystals; it is pellucid in the thin slices, and sometimes still retains a faint tinge of green. With polarized light, the colours are less diaphanous in aspect than those of the olivine, rich yellowish-brown and puce tints being common. The surface is rather variable, but generally moderately rough-looking, with often a slightly "stepped" aspect. The characteristic cleavage, as in augite, is commonly well developed.

The picotite occurs in very irregular grains or groups of grains, or even films, often looking as if a point armed with a sticky fluid had been drawn for a short distance along the slice. Surface rather

rough-looking, something like that of augite. Colour a translucent rather deep olive green, occasionally slightly inclining to brown, in No. IV. a rich umber brown. Rosenbusch (Mikroscop. Physiog. p. 160) gives the colours of picotite as yellow to brown, transparent to opaque; stating that Pleonaste differs from it in having green tints. If this distinction be correct, the mineral in slides I., II., III. must be Pleonaste. The grains are traversed by rather irregular cracks, which occasionally indicate a rude cleavage. IV. is less rich in picotite than the rest. As the mineral is isometric, it is of course dark between crossed prisms.

Of the various slides, No. I. is the best for study of the rock, as it is more coarsely crystalline, and shows little or no indication of decomposition. No. II. shows the grains of the minerals a little more rounded than No. I., and all are much cracked. The olivine appears to bear a rather smaller proportion to the other minerals than in I., and the diopside shows a rather smoother texture. The cracks in the olivine are often bordered on both sides by a finely fibrous serpentine, the result of decomposition. It remains bright, generally of a pale golden hue, between crossed prisms. No. III. is in structure similar to II., but with more olivine; here decomposition has advanced further, giving parts of the slide a muddy look, probably due to faint stains of peroxide of iron; the serpentine strings are often abundant enough to form a kind of network in the olivine, and one considerable crack across the slide is filled by a feebly double refracting serpentinous mineral. There is a sort of parallel structure perceptible in the direction of the principal cracks, marking a parallelism in the axes of the crystals, and the same is to a slight extent perceptible in the arrangement of the minerals.

No. IV. gives indications of a structure similar to III., but the change here is much more considerable. A network of serpentinous strings covers almost the whole slide, in many cases invading the other minerals; the cracks of which are usually free from serpentine in II. and III. In parts the strings seem to coalesce, so as to convert appreciable portions of the slide into serpentine. Here it is interesting to note that clots of opaque dust, doubtless oxides of iron, resulting from the separation of the constituents of the olivine, appear among the strings just as we see them, for example, in the Lizard serpentines.

These slides therefore exhibit to us, and this is the most interesting aspect of the rock, the commencement of the formation of serpentine. In certain serpentines—as, for example, those of Elba, and, as I have recently discovered, of the Lizard—and in some of the olivine bearing gabbros, we can trace the process from specimens from which all the olivine has disappeared, and the alteration into serpentine is complete, to those in which a considerable amount of unchanged olivine is still to be detected. We have thus a further confirmation of the idea, now becoming not unfamiliar to geologists, that much serpentine is an altered olivine rock.

Stphen Austin and Sons, Printers, Hertford.